Improved Trajectory Search Capability for Multi-Rendezvous and Flyby Missions (NELLS)

Completed Technology Project (2016 - 2017)
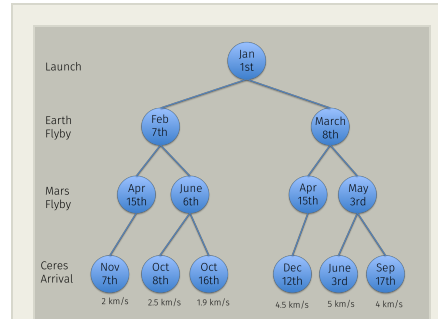
Project Introduction

This work made vital improvements to a primitive trajectory search algorithm known as NASA Exhaustive Lambert Lattice Search (NELLS). NELLS was created to work hand in hand as an initial guess generator for one of Goddard's primary preliminary design tools, EMTG, however NELLS currently lacks the capability necessary to design missions as the bodies visited increases.

Trajectory design involving high order (> 5) planetary, moon and small body flybys and rendezvous are exponentially more mathmatically complex than simpler ones. The objectives of this work were:

1. Improve the speed of trajectory generation by a factor of two for simple cases and an order of magnitude for complicated cases (trajectories that visit > 5 bodies). The runtime in NELLS for individual, complex cases was as high as two weeks. A more effective search algorithm, using modern computational science techniques--implemented in this work--reduced run times significantly, allowing more cases to be computed.
2. Create capability to rapidly generate multi-body trajectories which use deep-space maneuvers. Previously, NELLS was only capable of modeling four types of propulsion system impulses: launch, rendezvous arrival, rendezvous departure, and powered planetary flyby. These maneuver types cover a wide-range of missions, but there are some missions that simply cannot be flown without firing the spacecraft's propulsion system when not in proximity of a celestial body. Modeling of these so-called deep-space maneuvers is much more complex as there is no deterministic way of selecting the timing, size, and direction for every possible maneuver. However, a grid-search approach to placing such maneuvers provides a useful sample of the design space, which can later be optimized in other tools, and it is extremely important that such DSMs be considered, as they enable many mission designs to destinations such as the outer planets, and asteroids.

Anticipated Benefits

NELLS is now capable of automating a significant portion of trajectory design, which significantly decreases the time required for engineers to design missions in early phases. The new capability also allows engineers to investigate a much larger portion of the trajectory design space than was possible with the previous versions of NELLS.

Trajectory design constructed as a decision tree
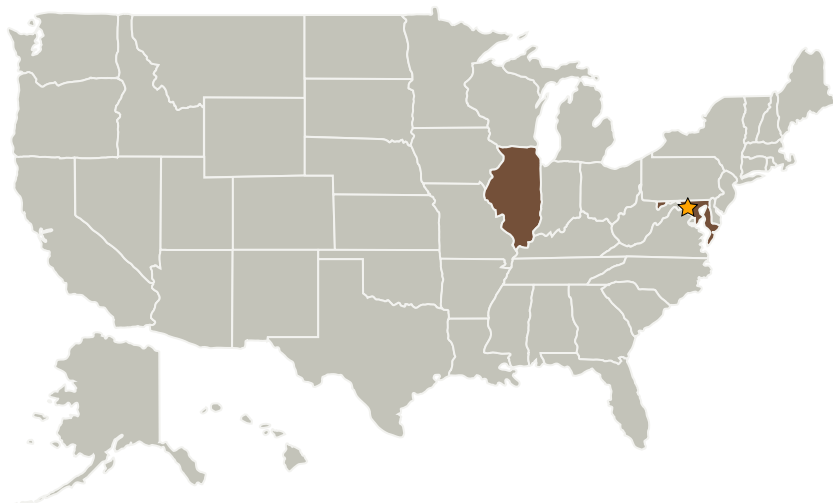
Table of Contents

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Primary U.S. Work Locations and Key Partners

Organizations Performing Work	Role	Type	Location
⭐Goddard Space Flight Center(GSFC)	Lead Organization	NASA Center	Greenbelt, Maryland

Co-Funding Partners	Type	Location
University of Illinois at Urbana-Champaign	Academia	Urbana, Illinois

Primary U.S. Work Locations	
Illinois	Maryland

Project Transitions

▶ **October 2016:** Project Start

Organizational Responsibility

Responsible Mission Directorate:

Mission Support Directorate (MSD)

Lead Center / Facility:

Goddard Space Flight Center (GSFC)

Responsible Program:

Center Independent Research & Development: GSFC IRAD

Project Management

Program Manager:

Peter M Hughes

Project Managers:

Jason W Mitchell
Timothy D Beach

Principal Investigator:

Jeremy M Knittel

Co-Investigator:

Kyle M Hughes

✅ **September 2017:** Closed out

Closeout Summary: The purpose of the Goddard Space Flight Center's Internal Research and Development (IRAD) program is to support new technology development and to address scientific challenges. Each year, Principal Investigators (PIs) submit IRAD proposals and compete for funding for their development projects. Goddard's IRAD program supports eight Lines of Business: Astrophysics; Communications and Navigation; Cross-Cutting Technology and Capabilities; Earth Science; Heliophysics; Planetary Science; Science Small Satellites Technology; and Suborbital Platforms and Range Services.Task progress is evaluated twice a year at the Mid-term IRAD review and the end of the year. When the funding period has ended, the PIs compete again for IRAD funding or seek new sources of development and research funding or agree to external partnerships and collaborations. In some cases, when the development work has reached the appropriate Technology Readiness Level (TRL) level, the product is integrated into an actual NASA mission or used to support other government agencies. The technology may also be licensed out to the industry.The completion of a project does not necessarily indicate that the development work has stopped. The work could potentially continue in the future as a follow-on IRAD; or used in collaboration or partnership with Academia, Industry and other Government Agencies.If you are interested in partnering with NASA, see the TechPort Partnerships documentation available on the TechPort Help tab. http://techport.nasa.gov/help

Images
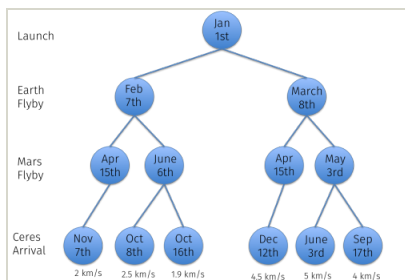
Trajectory Tree
Trajectory design constructed as a decision tree
(https://techport.nasa.gov/image/24490)

Project Website:

http://aetd.gsfc.nasa.gov/

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **6**

| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |

| Applied Research | Development | Demo & Test |
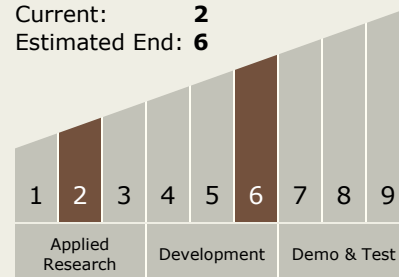
Technology Areas

Primary:

- TX11 Software, Modeling, Simulation, and Information Processing
  └ TX11.5 Mission Architecture, Systems Analysis and Concept Development
    └ TX11.5.1 Tools and Methodologies for Defining Mission Architectures or Mission Design

Target Destinations

Mars, Others Inside the Solar System, Foundational Knowledge

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https://techport.nasa.gov/view/90781

Page 3